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LUMINARY MEMO # 117

TO: Distribution
FROM: George R. Kalan
DATE: October 24, 1969
SUBJECT: Special Crew Procedures Necessary for Controlling the CSM-docked Configuration with the LM DAP

Due to the presence of jet plume deflectors on the LM descent stage, the use of +X thrusting LM jets for pitch or roll attitude control of the CSM-docked configuration will, for some mass loadings, cause a serious control instability if any -X thrusting jets have failed off or have been disabled. The problem can be explained with the aid of Fig. 1, which illustrates a typical jet pair firing about the U or V control axis to produce clockwise rotation about the center of gravity (CG). Because of impingement upon the jet plume deflector, the 100 lb +X thrusting jet produces a net force of 89 lb. in the +X direction acting on moment arm D_1 and a 59 lb. component perpendicular to the X axis acting on moment arm D_2. The net moment due to the firing of the +X thrusting jet, (M_{+X}), is expressed in Eq. 1.

$$M_{+X} = (89 \text{ lb}) D_1 - (59 \text{ lb}) D_2 \qquad \text{(Eq. 1)}$$

For many mass loadings, D_2 is large enough to produce a negative M_{+X}, indicating that the net moment produced by the +X thrusting jet tends to rotate the vehicle in the counterclockwise direction. Fortunately, in this situation the proper clockwise rotation will always be obtained if both the +X thrusting jet and the -X thrusting jet are fired simultaneously. Since, in the absence of disabled jets, the CSM-docked DAP always utilizes jet pairs for U or V axis attitude control, the only penalties for a negative M_{+X} in nominal operation are slower rotation rates and higher RCS propellant consumption. However, if a -X thrusting jet has failed off undetected or has been disabled manually, a U or V axis rotation

will eventually be attempted with a single +X thrusting jet. If M_{+X} is negative in this situation, a command for clockwise rotation will produce a counterclockwise rotation. Since the DAP will continue commanding the clockwise rotation with the +X thrusting jet, the vehicle will spin uncontrollably in the counterclockwise direction.

The approximate mass loadings for which M_{+X} is negative in the CSM-docked configuration are illustrated in Fig. 2. Whenever the LM DAP is used to control the CSM-docked configuration while mass loadings are in the shaded region of Fig. 2, the crew should manually disable all +X thrusting jets (jets 2, 6, 10, 14) to improve control authority and prevent the occurrence of the instability. The disabled jets may be enabled for +X translation or ullage only if the DAP is in the minimum impulse command mode. (The instability can not occur in this situation because the DAP does not attempt to control attitude in the minimum impulse command mode.) If, in addition to the disabled +X thrusting jets, some -X thrusting jets have been disabled, the DAP may not have enough jets available to control pitch, roll or yaw automatically. In such a situation, minimum impulse command mode should be entered and the +X thrusting jets should be enabled so that pitch and roll may be controlled manually with the Y and Z translational jets using the translational hand controller and yaw can be manually controlled with the rotational hand controller. *

Reference:

J. E. Jones, "Evaluation of the Effect of Jet Plume Deflectors Upon LM DAP Control of the CSM-docked Configuration - Simulation Results", Spacecraft Autopilot Development Memo #29-69, June 27, 1969.

* It has been assumed that the panel switches (which also disable jets 4, 7, 11, 16 when the +X thrusting jets are disabled) are used to disable the +X thrusting jets.

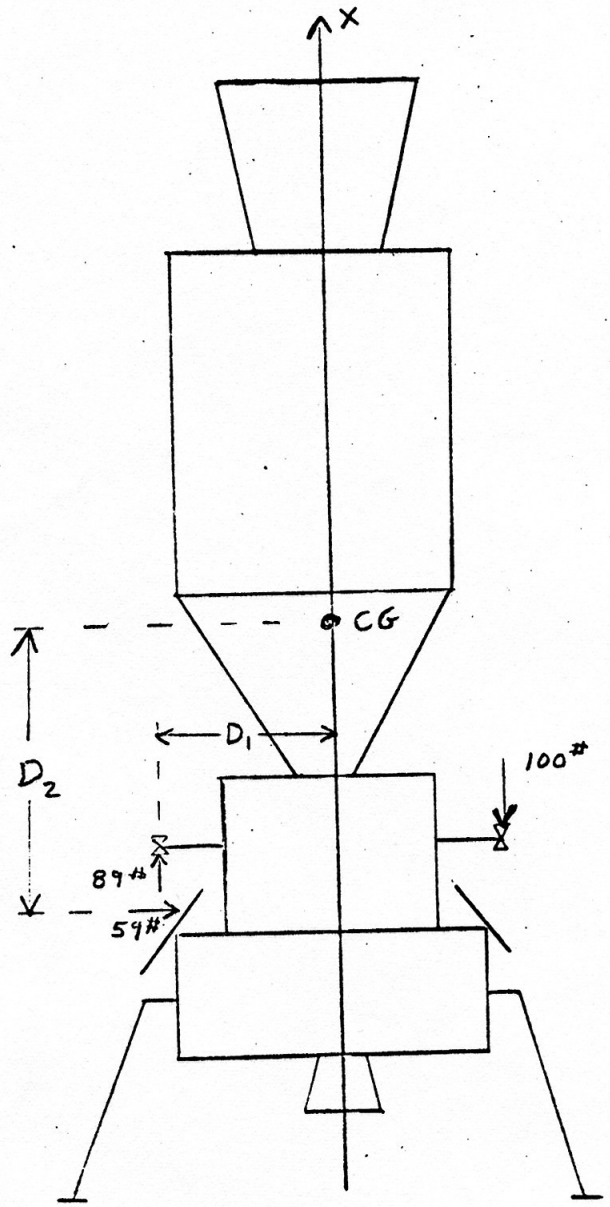
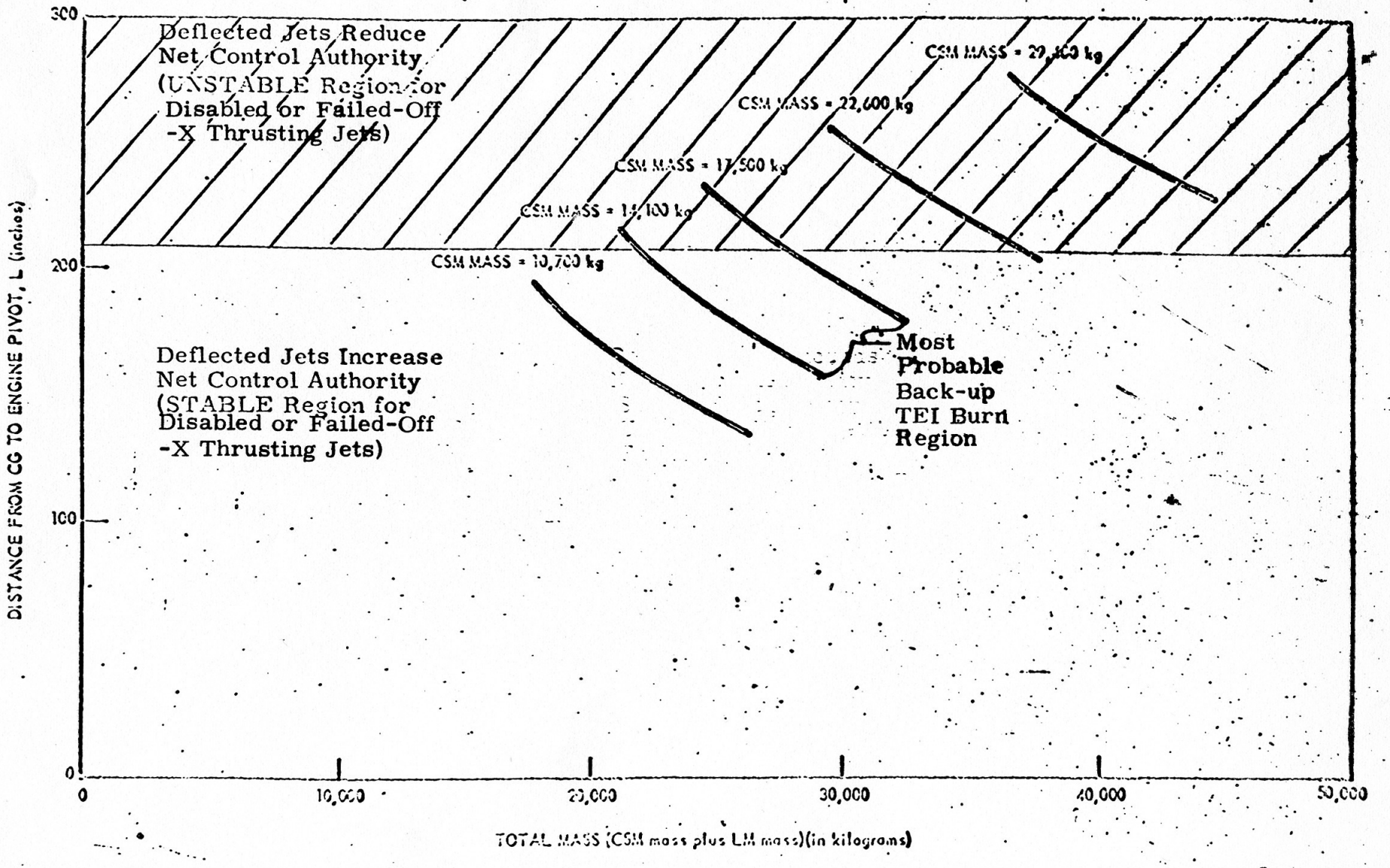


Figure 1



The computed hinge-pin-to-center-of-gravity distance, L, in the CSM-docked case.